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Fast Forced Handover Technique for Load Balancing in Mobile WiMAX for Real-time Applications

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Abstract

Mobile WiMAX is a wireless Metropolitan Area Network technology based on IEEE 802.16e standard which supports mobility for users. Huge number of mobile devices being used in WiMAX networks more than ever. However, these devices sustaining poor service quality and long delay due to network congestion. In order to solve these problems, a load balancing technique using Base Station (BS) initiated directed handover is proposed in this paper. The proposed technique called Fast Forced Handover Technique (FFHT). FFHT monitors the load-state in each BS and collect information about load-states of Neighbor BSs (NBSs). When congestion occurred at any BS, FFHT chooses Target BS (TBS). Furthermore, FFHT chooses candidate Mobile Stations to perform directed handover. In terms of handover delay, FFHT exchanges pre-handover control messages between serving BS (SBS) and NBSs to reduce delay and packet loss during handover process. FFHT is implemented using OPNET modeler 17.1. Its performance is evaluated based on an extensive simulation. The evaluation results demonstrate that the proposed technique distributes load efficiently in the whole network using light amount of control messages. FFHT assures Quality of Service (QoS) for all users in the network. The simulation shows how FFHT is suitable for real-time applications.

Keywords: Mobile WiMAX; Quality of Service; Fast Forced Handover; Load Balancing; Real-Time Applications.

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1. Introduction

Growing demand in the whole world on high speed broadband wireless networks led to motivate the development of new technologies in the field of wireless networks even suffice users requirements. Currently one of the most important broadband wireless access technologies in the world is the IEEE 802.16e standard which known as Mobile WiMAX[1]. It extends WiMAX to support mobility and wireless multimedia services. The most popular implementation of WiMAX standards is IEEE 802.16e. Therefore, this paper concentrated on IEEE 802.16e standard. WiMAX Forum® industry research report tells that WiMAX by 2011, there will be over 1 Billion people across the world within WiMAX coverage[2]. Now, WiMAX technology covers large geographical areas in Africa, Europe, Middle East and Americas3. In last few decades, Mobile devices with wide capabilities become more spread than ever. More real-time applications are used frequently on these mobile devices. These applications require high bandwidth and high speed connections with specific QoS level. Devices are suffering from poor service quality and long delay due to network congestion. Congestion occurred when load on network increases especially in rush hours at popular places. Therefore, network becomes unbalanced; some BSs have heavy traffic load and other BSs have light traffic load. On top of that, Mobile Station (MS) nodes suffer from high latency and intermittent connections in congested BSs. So, Load balancing schemes have been proposed for solving congestion problems. These schemes used MSs directed handover to distribute load among NBSs. Handover mechanisms in IEEE 802.16e can be classified as: Hard Handover (HHO) and soft handover[4]. The default handover procedure is HHO. There are two optional types of soft handover called Fast Base Station Switching (FBSS) and Macro Diversity Handover (MDHO)[5]. Handover latency and packet loss are the parameters that real-time applications suffer from and they are considered major concerns in Mobile WiMAX[6]. Load balancing techniques proposed to distribute load among NBSs to solve problems resulting from congestion. Some proposed techniques require extensive amount of signaling[7] and presence of a centralized architecture. Some other techniques are not suitable for real-time applications[8] because of long handover delay and high packet loss rate. In FFHT, we overcome these limitations where Pre-handover messages sent directly among NBSs to select TBS and reduce handover delay. By using these control messages, SBS can reserve resources for MS on TBS. FFHT work using small amount of signaling. This paper touches on the following contributions:

1. FFHT is an efficient and fast load balancing technique which using triggered not periodic control messages.
2. FFHT defines BS load-state based on QoS parameters.
3. FFHT doesn't require any modifications in current Mobile WiMAX network architecture.
4. FFHT uses fast handover technique to reduce handover delay and packet loss which make it suitable for real-time applications.
5. FHT reduces the number of blocked calls and avoids “Ping-Pong” effect.

The experimental study presented in this paper demonstrates that FFHT reduced handover delay and packet loss. In addition, it reduced call blocking rate and it is suitable for real-time applications.

The rest of this paper is organized as follows: Background and related work discussed in Section 2. The proposed technique and its phases introduced in Section 3. Section 4 introduces evaluation of the proposed technique and result analysis. Conclusion has been drawn in Section 5.

2. Background and Related Work

Mobile WiMAX technology supports multimedia services with QoS and mobility for MS nodes. However, MSs face some problems when traffic load increases in the network. Therefore, Mobile WiMAX defines a set of load balancing techniques used to solve congestion problems. Most of proposed load balancing techniques use directed handover to alleviate traffic load in congested BS. However, MSs Packet loss increased as a result of handover delay which is an important issue with real-time applications. The HHO is a Break-Before-Make procedure[5], in which the MS breaks its connection with the SBS then makes a new connection with the TBS. HHO is less complex, high latency and not suitable for real-time applications. So, the proposed FFHT uses modified HHO technique called Passport Handover[9] due to its simplicity and low distortion time.

2.1. Background of Load Balancing Techniques in Mobile WiMAX

A load balancing scheme called Spare Capacity Procedure (SCP) has been proposed in[10]. This scheme broadcasts Spare Capacity Report (SCR) among NBSs every Load Balancing Cycle (LBC). SCR contains the uplink and downlink available radio resources in the BS. BS uses SCR information as an indicator of the feasible set of TBS. when SBS receives SCR from NBS, SBS then computes L and T. Where T is a Threshold calculated from Eq. 1.

$$T = L + \partial L \tag{1}$$

L represents the average load level and δ represents hysteresis margin which used to avoid "Ping-Pong" effect. The BS load-state is Underloaded if (U <L). If (U>L), the load-state becomes Overloaded. Load-state become Balanced if (L<U<T). If load-state becomes Overloaded, SBS triggers LB scheme. When LB is triggered, the BS will initiate directed handovers for MSs that reside in overlapping areas. SCP doesn't take into account the service level and QoS for MSs that will execute directed HO but it enhance system wide resource utilization.

QoS and resource scheduling become an important issue in Mobile WiMAX with the increased use of real-time applications. Therefore, The required service can be mapped onto one of the following scheduling service classes[11]; real-time Polling Service (rtPS), extended real time Polling Service (ertPS), not-real-time Polling Service (nrtPS), Unsolicited Grant Service (UGS) and Best Effort (BE). The QoS concept in the IEEE 802.16e is related to connection, service classes and service flow concepts. After initial ranging between MS and SBS, a connection identifier (CID) is set up. A service flow is uniquely identified by a 32-bit Service Flow Identifier (SFID) [12]. WiMAX relate the service flow with a well-defined CID. Each service flow is mapped onto a connection and each connection will belong to one of the scheduling data services on the basis of the required QoS[12].

In[13], a QoS aware scheme proposed for load balancing in Mobile WiMAX. It called WiMAX QoS Aware Load Balancing Protocol (WQLB). The main focuses of this scheme are how to define BS load, how to detect overloading and execution of handover operation. In overload detection, the proposed method takes all of performance parameters of QoS classes into account. In a handover operation, some of MS nodes residing in the overlapping area are chosen to be transferred to neighbouring BS. Every LBC, the SBS compares its Load matrix (LM) with the Threshold matrix (TH) and Hysteresis Margin matrix (HM) where

$$[TH] = [TH] + ([TH] * [HM]) \tag{2}$$

If elements of load matrix of BS (LMBS) have passed the TH matrix of the above formula, BS notifies that it is in an overload state. If the SBS is in overload state, it finds MSs residing in overlapped area to switch its connection to TBS. Since BSs are communicating with each other through ASN gateways, they know their adjacent BSs situations in advance. Chosen MSs in the candidate list then execute Forced Handover to TBS. WQLB distribute load efficiently using QoS parameters but still has long handover delay.

In[14], an advanced load balancing technique proposed based on network controlled handover. However, the deployment of this algorithm requires extensive amount of signaling and presence of a centralized architecture is preferred. In[7] an inter-frequency reuse handover among frequency assignments is suggested to solve unbalanced load distribution in IEEE 802.16e networks. This scheme is not controlled by network. In[8] the proposed algorithm use dual handover mechanism where MS and BS initiated handovers are used adaptively. However, this procedure is not suitable for real time applications. A novel handover algorithm to balance the load of the layers in a multi-reuse scenario in mobile WiMAX systems is proposed in[15]. In[16] a new distributed uplink packet scheduling algorithm in WiMAX networks is proposed. The uplink available resources were estimated for each connection in this algorithm to provide required resources and guarantee QoS requirements of each connection in the same time. In[17] a modified mechanism proposed for HHO that reduce the number of control messages to make the handover acceptable for real-time applications. This technique reduces handover latency by about 50%. In[18] an evaluation study between load balancing trends introduced. This evaluation study showed that WQLB achieved load balancing efficiently but with longer distortion time and packet loss was greater than SCP.

3. Proposed Fast Forced Handover Technique (FFHT)

In this section, we propose a new Fast Forced Handover Technique for load balancing in WiMAX networks. FFHT ensure the implementation of the terms of QoS between MSs and BS for real-time applications. We can divide load balancing mechanism using FFHT into three phases; Topology Acquisition Phase, Load-State Monitoring Phase and Fast Forced Handover Phase. The three phases will be discussed in the following subsections.

3.1. Topology Acquisition Phase (TAP)

In this phase, the BS broadcasts MOB_NBR_ADV message periodically to MS nodes. This message includes the BS_IDs and Downlink/Uplink Channel Descriptor (DCD/UCD) of the NBSs to enable MS to synchronize with NBSs as shown in Fig. 1. Therefore, MOB_SCN_REQ message is sent from MS to SBS. This message indicates NBSs, scanning duration, the interleaving interval, and the number of scanning iterations. MOB_SCN_RSP message sent from SBS includes start frame and duration or rejects the request. MS start scanning after M frames from receiving the MOB_SCN_RSP message. The SBS buffer incoming data come to the MS and then transmit that data during any interleaving interval after scanning mode.

In the proposed FFHT, three load-states are defined to reflect the state of each BS in the network. These states are Overloaded state, Balanced state and Underloaded state. Overloaded state means that this BS serves large number of MS nodes and there is congestion. Balanced state means that this BS serves appropriate number of MS nodes. There is no congestion and can accept minimum number of directed handovers. Underloaded state means that this BS serves small number of MS nodes.

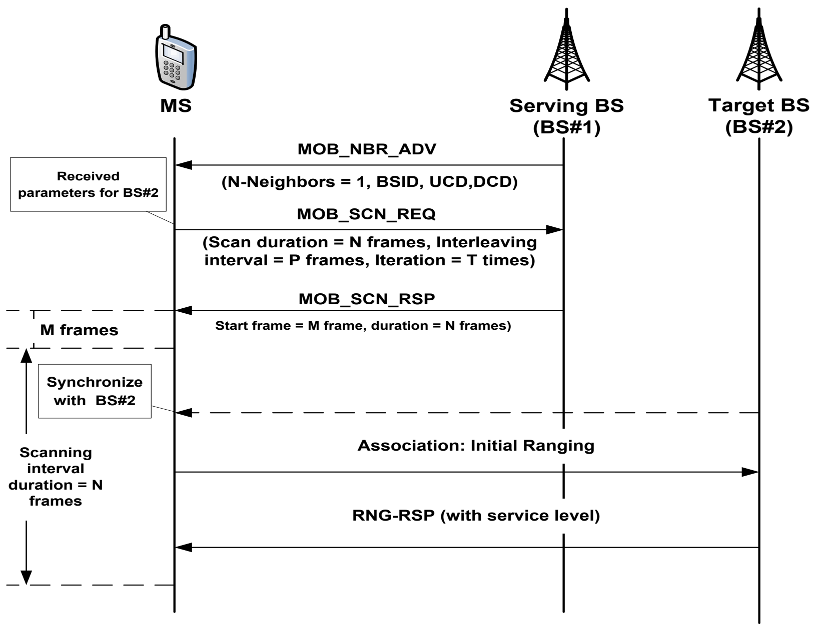

Fig. 1. WiMAX NBS advertisement and scanning with level-0 association.

There is no congestion and can accept large number of directed handovers. Load- state identified based on the performance parameters of the five service classes and free slots in uplink and downlink connections. We defined total capacity for each BS for real-time applications that equal the summation of total capacity for UGS, rtPS and ertPS traffic in the BS as shown in Eq. 3.

$$TCapacity_{BS} = [TCAP_{UGS} + TCAP_{rtPS} + TCAP_{ertPS}] \tag{3}$$

Where TCAPUGS represents BS total capacity for UGS traffic as shown in (4), where x1 represent throughput in Uplink, x2 represent throughput in downlink, x3 represent number of UGS free slots in the Uplink and x4 represent UGS free slots in downlink. TCAPrtPS represent total BS capacity for rtPS traffic and TCAPertPS represent total BS capacity for ertPS traffic.

$$TCAP_{\mathbf{UGS}} = [x\,1; x\,2; x\,3; x\,4] \tag{4}$$

Current capacity of any BS is calculated from Eq. 5 that is the summation of the current actual traffic capacity for UGS, rtPS and nrtPS.

$$CCapacity_{\mathbf{BS}} = [CCAP_{\mathbf{UGS}} + CCAP_{\mathbf{rtPS}} + CCAP_{\mathbf{ertPS}}] \tag{5}$$

BS load-state becomes Underloaded for any traffic type (rtPS for example) if current capacity is less than 50 % of total capacity [CCAPrtPS < (0.5 * TCAPrtPS)], load-state become Balanced, if current capacity is greater than 50% of total capacity and less than 75% of total capacity, [(0.75 * TCAPrtPS) > CCAPrtPS > (0.5 * TCAPrtPS)] and become Overloaded if [CCAPrtPS > (0.75 * TCAPrtPS)] as shown in Fig. 2. By the end of this phase, each BS in the WiMAX network constructs two lists. One list contains Underloaded BSs named U_BS_List and the other list for Balanced BSs named B_BS_List. BS put all neighbor BSs in the U_BS_List because at startup all neighbors BSs assumed to be in Underloaded state.

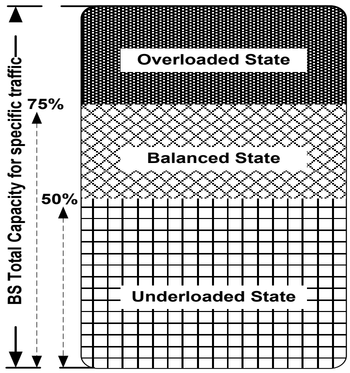

Fig. 2. BS Load-state declaration for any traffic type.

3.2. Load State Monitoring Phase (LSMP)

In this phase, each BS in the WiMAX network monitors its load-state. Two lists were constructed from Topology Acquisition Phase (TAP); a list of Balanced NBSs and a list of Underloaded neighbor BS. These lists look like Topology table. We assumed that, at startup all BSs load-states are in Underloaded states by default, even load- state changed to Balanced or Overloaded. If BS load-state changed from Underloaded to Balanced, BS immediately sends trigger Load_State_Msg to all NBSs. This message contains BS_ID and L=0 that is an indicator to Balanced state. Neighbor BSs will remove this BS from U_BS_List and add it to B_BS_List. If load-state changed from Underloaded state to Overloaded state, Load_State_Msg that contains BS_ID and L=1 that indicates to Oveloaded state sent to all neighbor BSs. Neighbor BSs will remove BS from U_BS_List. When load-state changed from any state to Underloaded, BS immediately send a Load_State_Msg to all NBS; this message contains BS_ID and L= -1 that indicates to Underloaded state. Neighbor BSs will add BS to U_BS_List and remove it from B_BS_List if exists. In this phase of FFHT, all BSs send triggered updates when load-state changed. So FFHT don't need extensive amount of control messages. In all load balancing techniques, periodic control messages sent among BSs every Load Balancing Cycle (1 second) as proposed in[13] and[10]. When congestion occurred and BS load-state becomes Overloaded, SBS triggers FFHT and select TBS that will be in the U_BS_List or in B_BS_List. If U_BS_List is empty, it will choose from B_BS_List. If B_BS_List is empty also FHO will fail. When TBS chosen, SBS sends Pre_Ho_Notification message to TBS that contains Serving BS_ID, MS_ID, bandwidth required capabilities and QoS parameters as shown in Fig. 3. TBS admit BS resources for new MS. TBS send Pre_HO_accept message to SBS with ACK for acceptance or NACK for rejection. If TBS accept, SBS sends Pre_HO_confirm message to TBS contains BS_ID, MS_ID and 16-bit current connection identifier (CID) as discussed in[9] for passport handover. If TBS reject, SBS will choose another TBS that is the next BS in the U_BS_List or in B_BS_List.

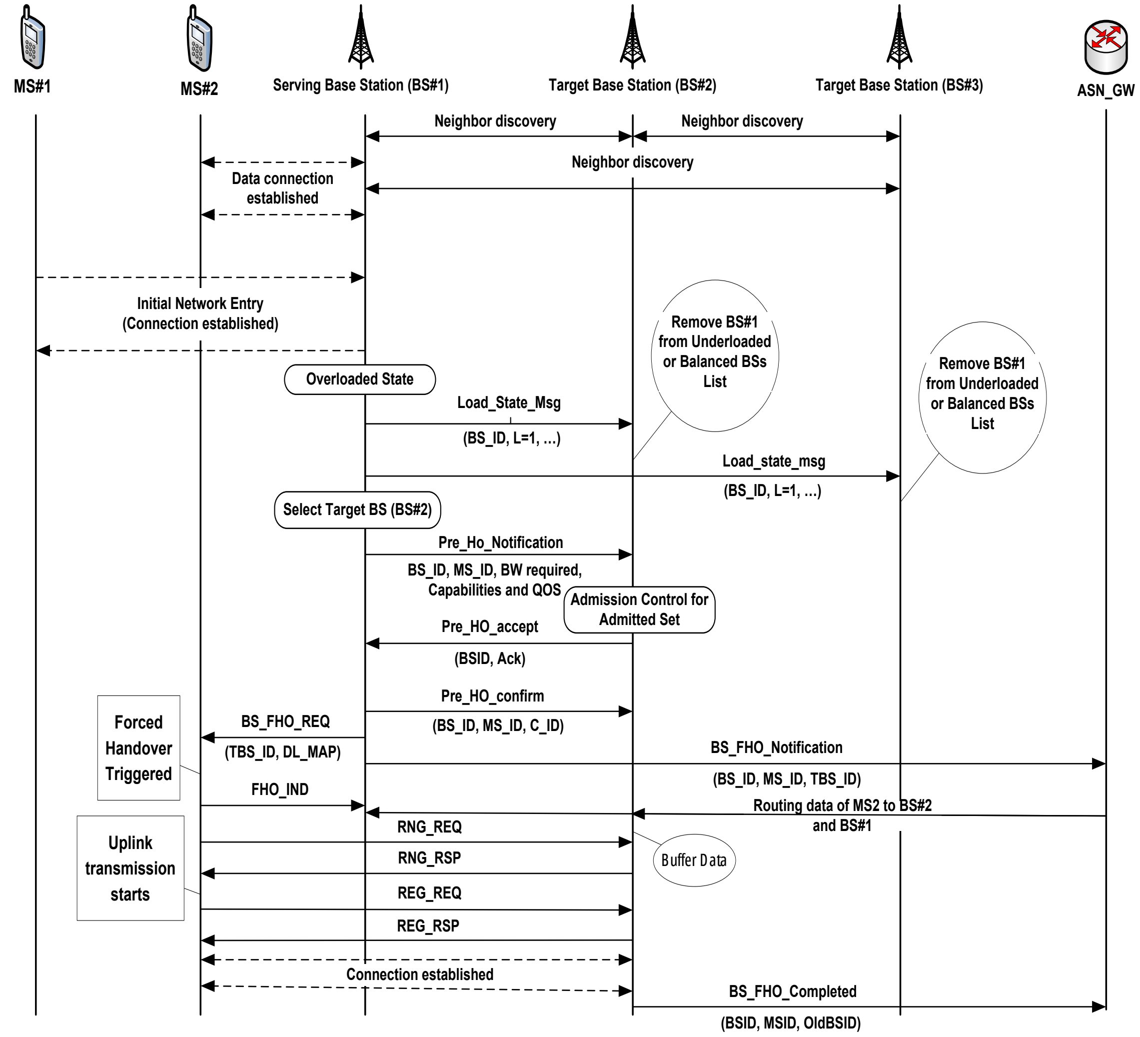

Fig. 3. Proposed FFHT Load Balancing mechanism in WiMAX network.

3.3. Fast Forced Handover Phase (FFHOP)

The next step after choosing target BS is choosing candidate MS nodes that will execute forced handover with chosen TBS. SBS will choose MS nodes that reside in the overlapping area with TBS. If there is no MS nodes in overlapping area with TBS, SBS will choose another TBS. SBS then send BS_FHO_REQ message to candidate MS that contains TBS_ID and DL_MAP of TBS. In the same time, SBS send BS_FHO_Notification message to ASN_GW that contains serving BS Identifier (SBS_ID), Target BS Identifier (TBS_ID) and MS Identifier (MS_ID). This message sent to inform the ASN_GW to route data for MS to TBS and SBS in handover time. MS send FHO_IND message as a response on BS_FHO_REQ message to release the connection with serving BS as shown in

Fig. 3. MS then performs initial network entry with TBS. In this step, initial ranging activity time reduced to reduce handover latency and packet loss to be suitable for real-time applications .The CID assigned by SBS will be accepted by TBS during the handover until new CIDs are assigned. A group of CIDs are reserved specially for forced handover between neighbor BSs to facilitate fast handover for real time applications and reduce handover latency. New SBS will buffer data of MS during handover time. MS start synchronization with downlink of TBS then receive RNG_RSP message from TBS contains basic and primary CID. Then MS start synchronization with uplink TBS. MS then send REG_REQ message to TBS to acquire new CID. TBS reply with RNG_RSP message with valid new CID that makes old CID is invalid. BS_FHO_Completed message sent from new SBS to ASN_GW to inform that forced handover completed successfully and data for MS routed to new SBS only. ASN_GW send all new data of MS to new SBS. SBS send buffered data and new data to MS, Data buffering by SBS reduced data loss.
As presented in[9], the service disruption period reduced to 50ms instead of conventional 200ms. For this reason, we choose this technique in handover execution between MS node and TBS. The service interruption time for proposed technique calculated from Eq. 6.

$$D_{\mathbf{proposed}} = T_{\mathbf{sync}} + T_{\mathbf{cont\_resol}} + T_{\mathbf{rng}} \quad (6)$$

Where Tsync is the average time for synchronization with downlink of new BS and its default value is 20 ms. Tcont_resol is the average time for contention resolution and its value equal zero when there is a dedicated ranging slot. Trng is the average time required for ranging process with new BS and its default value is 30ms in this phase. FFHT executed in time smaller than consumed in SCP and WQLP and other techniques.\

4. Simulation and Result Evaluation of the Proposed Techniques

In this section, FFHT will be evaluated using OPNET Modeler 17.1[19]. OPNET Modeler lets user to test and demonstrate technology designs before production, develop proprietary wireless protocols and technologies and evaluate enhancements to standards-based protocols[20]. A simulation platform is built to evaluate the proposed technique; by simulating an ASN access network with cluster of seven adjacent Base Stations residing in hexagonal layout. Each BS is 2km cell radius and there is an overlap distance between BSs equal 200 meters. All BSs connected to the same ASN-GW. It is assumed that there is no IP Layer re-anchoring required because all BSs are under the same ASN-GW. Groups of MSs are fixed nodes and the remaining nodes are mobile nodes with custom trajectory and speed is 100km/h. VOIP service that represents real-time service is served in the simulated network. FTP service that represents non real-time services also included in the simulated network traffic. The physical profile used for MS nodes and BSs is Wireless OFDMA 20 MHZ, QPSK 1/2 for Modulation and Encoding. The destination for all the traffic is the Server node which has all application services used in the simulation. Simulation runs for 300 simulation seconds. The traffic will be a mixture of UDP based VOIP traffic (PCM quality speech) served by Unsolicited Grant Service (UGS) and TCP based FTP traffic served by Not-real-time Polling Service (nrtPS). The MS nodes will distributed to the system as shown in Table 1. At the end of simulation, the number of MS nodes will increased by 40 new MS nodes to be 300 MS nodes. Table I shows also the load-state of each BS at the beginning of simulation.

Table 1. The Number of MSs Associated with Each BS.

Base Station	Mobile Station Number	BS Load-state
BS1	80	Overloaded
BS2	20	Underloaded
BS3	15	Underloaded
BS4	25	Underloaded
BS5	40	Balanced
BS6	40	Balanced
BS7	40	Balanced

4.1. Evaluation of BSs Resource Utilization Using FFHT

In WiMAX networks, optimal allocation and utilization of radio resources between MS and BS is a major challenge and a great concern. In this subsection, resource utilization evaluated without using any load balancing technique and with using FFHT. FFHT result is compared with WQLB and SCP load balancing techniques. Efficient resource utilization in the whole network and distribution of load between neighbors BSs with QoS guaranteed for all MSs without using huge amount of control messages is our target. When the system doesn't use load balancing and directed handovers are not applied, system becomes unbalanced where BS1 have largest number of MS nodes and other BSs have fewer MS nodes. We observed that the UGS traffic in Overloaded BS1 consumes high resources reached 95% of BS capacity as shown in Fig. 4 (a). But in Balanced BS3, BS5 and BS7 UGS traffic consumes medium resource reached 40% of BS capacity. In Underloaded BS2, BS4 and BS6 UGS traffic consumes low resources around 30% of BS capacity because there are few number of MS nodes served in these BSs.

In Fig. 4 (b), when FFHT used to balance load between cells, the resource utilization for BS1 decreased to be near 45% and forced handover occurred to distribute a group of MS nodes reside in overlapping area to move to Underloaded NBSs (BS2, BS4 and BS6). Forced handover triggered twice in BS1, at the beginning of simulation where BS1 resource utilization increased to reach 85% and at time equals 160 seconds when new 40 MS nodes entered BS1 cell range. BS1 has two lists; the first List is U_BS_List that has Underloaded BS2, BS4 and BS6 and the second List is B_BS_List that has Balanced BS3, BS5 and BS7. BS1 send MS nodes to BS2, BS4 and BS6 that are in U_BS_List. BS1 distribute load equally among BS2, BS4 and BS6 to make whole network balanced in traffic load and not to load on specific BS without the others.

In Fig. 4 (c,d), WQLB and SCP distributed load with neighbors BSs based on QoS parameters. SCP checks free slots in the uplink and downlink in SBS to determine load-state. At the beginning of simulation, load balancing technique triggered and BS1 make unequal load distribution with neighbors BSs. WQLB and SCP toke longer time to reach balanced state at the whole network than FFHT.

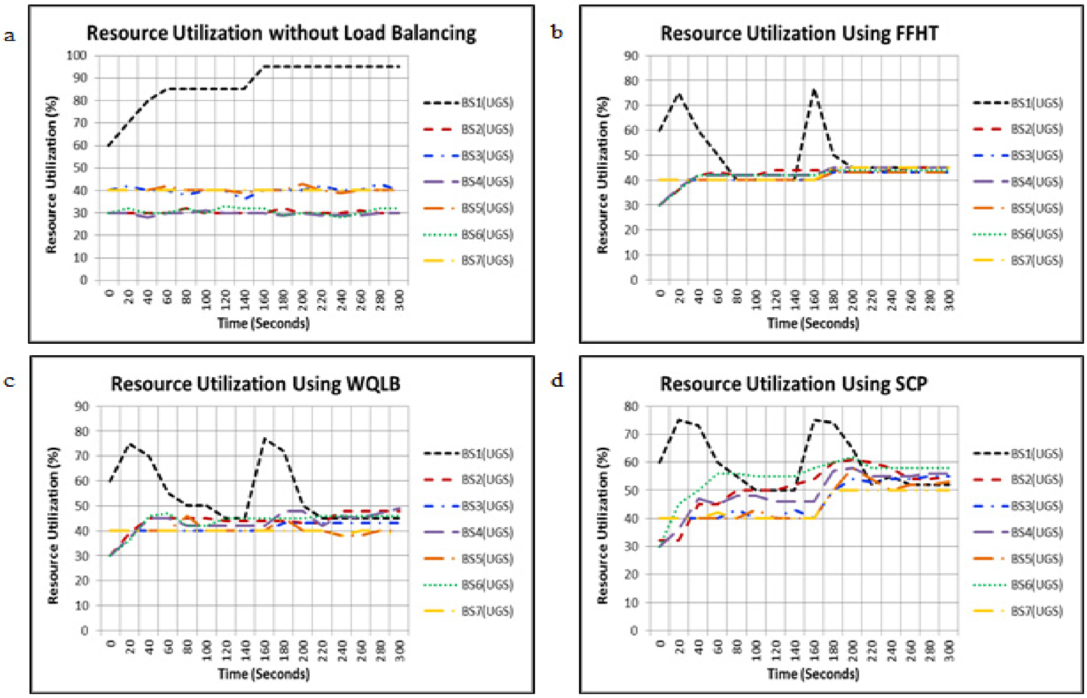

Fig. 4. (a) BS resource utilization without using any load balancing techniques; (b) BS resource utilization using FFHT; (c) BS resource utilization using WQLP; (d) BS resource utilization using SCP .

4.2. Load Balancing Cycle Evaluation in FFHT

In this subsection, Load Balancing Cycle (LBC) was evaluated to show how this value affects resource consumption in the overloaded BS and the time that taken to reaches Balanced state from Overloaded state. SBS check its Load-state every LBC. If LBC has large value, load balancing technique doesn't work efficiently. If LBC has very small value, load balancing technique will triggers unnecessary handovers. The default value of LBC is 1second as considered in[13]. In this paper, we examined LBC with different values in our simulated WiMAX network; LBC examined with values 30 seconds, 20 seconds, 10 second and 1 second. Simulation results showed that LBC with value equal 1 second give best resource utilization with Overloaded BS1 as shown in Fig. 5.

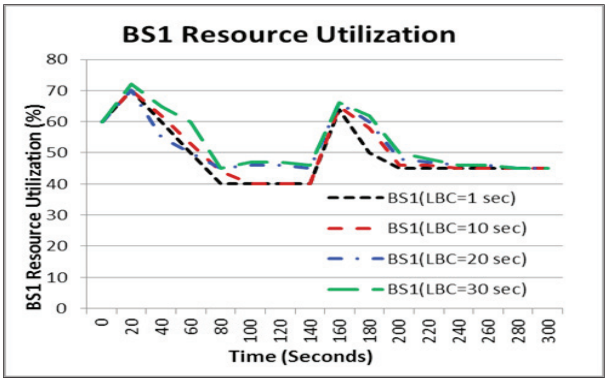

Fig. 5. (a) BS1 Resource Utilization with different LBC values.

4.3. Evaluation of FFHT Disruption Time and Throughput

Disruption time is the time taken during MS handover process with TBS. In the disruption time, throughput could be zero because the service is interrupted due to synchronization and ranging with TBS. In this subsection, FFHT time evaluated, analyzed and compared with other load balancing schemes. Passport handover technique used in handover process, so FFHT equals 50 ms as declared in Eq. 4. As shown in Fig. 6 disruption time in FFHT is the smallest disruption time compared to WQLB and SCP. FFHT disruption time is near 50ms but in WQLB near 200ms and in SCP near 150ms. Low disruption time means low packet loss. WQLB and SCP use conventional handover techniques to achieve load balancing. With real-time applications this long disruption time is not suitable. So, our proposed FFHT with low latency, fast convergence and low data loss is suitable for real-time applications.

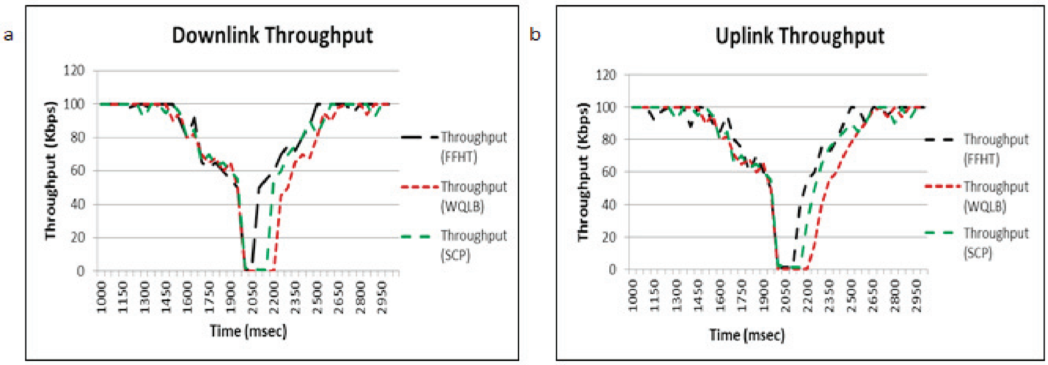

Fig. 6. (a) Downlink throughput; (b) Uplink throughput.

5. Conclusion

Load Balancing eases the heavy load and improves resource utilization in congested BSs in WiMAX networks. BS-initiated handovers used to achieve load balancing in the whole network. However, handover latency is a great concern for real-time applications that reduce data throughput. In this paper, a FFHT proposed to balance load in the whole network and reduce handover latency and data loss to suite real-time applications. Moreover, FFHT prevent "Ping-Pong" effect and don't use extensive amount of signaling among NBSs. FFHT uses trigger update messages among NBSs. Simulation results showed that proposed technique can distribute load in the whole network efficiently and respond to load-state change quickly by sending triggered control message to all neighbors. Moreover, handover latency has been reduced to be 50ms to work with real-time applications. FFHT compared with another load balancing techniques such as WQLB and SCR, FFHT give high throughput and low distortion time. FFHT don't use specific structure deployment for WiMAX, it operates well with any structure.

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